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# Electrophysiological Changes in P200 Latency and Amplitude of Jittered Orientation Visual Integration Task in Healthy Participants: a Multi-Block Design EEG Study

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## Recommended Citation

Rozynski, Monika M. and Chen, Chi-Ming, "Electrophysiological Changes in P200 Latency and Amplitude of Jittered Orientation Visual Integration Task in Healthy Participants: a Multi-Block Design EEG Study" (2015). *Honors Scholar Theses*. 433.  
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a Multi-Block Design EEG Study

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Honors Thesis

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Spring 2015

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### Abstract

Visual integration, the ability to fuse environmental information such as light, color, shades, and motion to form a representation of a whole cohesive higher-order visual image, is impaired in persons with schizophrenia. Little is known how the P200 component, an event-related potential (ERP) in the parieto-occipital region, is affected in persons with schizophrenia while they perform visual integration tasks, when compared to healthy persons. This study administered Gabor contours that varied in high and low degrees of orientational jitter through the Jitter Orientation Visual Integration (JOVI) task to investigate visual integration by analyzing latency and amplitude of the P200 component. Data was acquired via EEG from seventeen healthy participants. The purpose of this study was to assess difficulty of jitter on the latency and amplitude of P200, and the electrophysiological effect from practice when comparing the last block data with the first block data. The mean amplitude of the hard difficulty jitters (11, 13, and 15 degrees) was found to be significantly larger than that of the easy difficulty jitters (0, 7, and 9 degrees). A trend in the latency of P200 between hard difficulty and easy difficulty was found. No interaction between blocks and latency and amplitude was found. Data from this study will be further used and analyzed when EEG data is acquired from patients with schizophrenia in the upcoming years.

*Keywords:* P200, integration, latency, amplitude, EEG, JOVI, schizophrenia

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Schizophrenia, a mental disorder that causes visual and auditory hallucinations, delusions, disorganized thinking and behavior, depressive-like symptoms, and cognitive impairments affects approximately 2.5 million Americans (National Institute of Mental Health). The psychopharmacology for treatment for schizophrenia, and behavioral profiles have been extensively studied, but only recently has great interest been expressed in understanding the neurological processes underlying the disease (Silverstein et al., 2011). The Cognitive Neuroscience Treatment Research to Improve Cognition in Schizophrenia (CNTRICS) is an initiative that started in 2011 to focus neuroscience on finding treatments for impaired cognitive systems in humans. Visual integration, one of the four core paradigms in the CNTRICS initiative, is the process that fuses local visual environmental information such as light, color, shades, and motion to form a cohesive complex higher-order visual image; people with schizophrenia are known to have deficits in this type of visual perception (Kozma-Wiebe et al., 2006; Silverstein et al., 2011; Wynn et al., 2015). Interestingly enough, it is suggested that the reduced ability to organize stimulus segments at the neuronal level is correlated to clinical behavioral aspects of disorganization (Silverstein, 2000).

The neural systems underlying the visual systems are complex, and perceptual organization cannot be localized to a specific brain region or latency (Silverstein & Keane, 2011). The visual system consists of the magnocellular and parvocellular pathways which start in the retina, project through the lateral geniculate nucleus, and synapse on the different layers of V1, the primary visual cortex (Butler, Silverstein, & Dakin, 2008). The magnocellular pathway

extends to the dorsal parieto-occipital stream that is involved in eye movement control, motion perception, and visual as well as somatosensory integration where the global motion of large complex objects is processed (Butler et al., 2008). The parvocellular pathway extends to the ventral temporo-occipital stream where orientation and size in V1, contour and form in V2, and shape in V4 are processed due to its main role in object recognition (Ungerleider & Pasternak, 2004; Butler et al., 2008). Data from a study by Silverstein et al., 2009 using BOLD signal and fMRI data suggest that V2, V3, and V4, the higher-order visual areas in the ventral temporo-occipital stream are underactivated during visual integration processes in schizophrenic patients when compared with healthy individuals.

Visual integration can be studied using variants of a contour integration paradigm (Silverstein et al., 2011). In our study, visual integration was examined using the Jittered Orientation Visual Integration (JOVI) task. JOVI utilizes Gabor shaped luminance patches, which are Gaussian-modulated sinusoidal luminance variations that resemble the structure of the receptive field orientation simple cells in the primary visual cortex, V1 (Kozma-Wiebe et al., 2006; Silverstein et al., 2011). When adjacent line segments, or in this example, Gabor patches have similarly oriented long-axes, they are perceptually grouped together as part of a coherent visual contour (Kovács, Polat, Pennefather, Chandna, & Norcia, 2000; Li & Gilbert, 2002; Silverstein et al., 2009). For example, Figure 1 C illustrates an egg-shaped contour pop-out constructed with an 18 element Gabor patch surrounded by many distractor Gabor patches with uncorrelated orientations. All contours in Figure 1 had a 5 cycles/degree spatial frequency and contrast was approximately 95% (Silverstein, Kovács, Corry, & Vallone, 2000). As the Gabor patch orientation correlation is reduced, the perceived contour no longer segments or pops-out from the distractors (Silverstein et al., 2009). Task performance by people with schizophrenia

using simple, closed contours, for example, showed unimpaired results due to little integration cortical processing needed, but the visual integration processing was impaired with non-closed, complex images that need to be perceptually integrated into a whole (Silverstein et al., 2009). The perception of the Gabor contour requires the receptive field orientation simple cells in V1 to code the orientation-correlated contour line segments (Li and Gilbert, 2002; Kozma-Wiebe et al., 2006; Silverstein et al., 2009). Higher visual areas such as V2, V3, and V4 are where coherent contour visual information is initially grouped and, as a result, are also involved in field orientation feedback (Silverstein et al., 2009).

Our study uses the JOVI task and an electroencephalogram (EEG) to measure event related potentials (ERPs), which are ideal due to their ability to access different stages of integration processing because of their high temporal resolution (Butler et al., 2013). We are mainly focused on the P200 component, a parieto-occipital region ERP. P200 is a positive-amplitude spike in neural activity approximately 125-275 milliseconds after a stimulus is presented (Schizophrenia Research Institute: P200-EEG, 2013). P200 has been proposed as a biological marker for schizophrenia in terms of amplitude and latency (Schizophrenia Research Institute: P200-EEG, 2013). Very little is known about the nature of the P200 ERP component or its' role in schizophrenia processes (Wynn et al., 2015).

The purpose of this study was to use EEG to investigate visual integration in healthy participants and examine amplitude and latency of P200 of hard and easy jitter orientation difficulties. As aforementioned, Silverstein et al. (2009) found that as the contour orientation jitter gets higher, the perceived contour segmentation is reduced (Silverstein et al., 2009). Butler et al. (2013) found that the N120 and closure negativity (Ncl) components showed a significant amplitude difference between low versus high jitter stimuli, and ERP current source density

response effects between patients with schizophrenia and controls in P100 showed a significant difference but did not examine P200 in their study. Here, we hypothesized that P200 latency and amplitude will be longer and larger respectively, when perceived contour segmentation is reduced due to orientation jitter. Pernet et al. (2003) suggest that P200 is involved with implicit memory of stimuli, due to their findings of over-learned stimuli resulting in short P200 latency and unfamiliar stimuli resulting in longer P200 latency. These findings suggest that there could be a potential electrophysiological effect from practice between blocks. Accordingly, we hypothesized that there would be an electrophysiological effect from practice when comparing the 4<sup>th</sup> block data with the 1<sup>st</sup> block data.

## **Method**

### **Measures**

Participants took part in a medical and psychiatric screening that was used to exclude participants with any possible psychological disorders. They also participated in a vision test to check for any vision issues. Participants were first screened by a general medical history evaluation form, Edinburgh Handedness Questionnaire (Oldfield, 1971), and then, participated in a Structured Clinical Interview for DSM Disorders, non-patient version (SCID-I/NP) (First, Spitzer, Gibbon, & Williams, 2002) as well as a Brief Visuospatial Memory Test (BVMT) (Benedict, Schretlen, Groninger, Dobraski, & Shpritz, 1996). Sensory Gating Inventory (SGI) (Hetrick, Erickson, & Smith, 2012), and the Schizotypal Personality Questionnaire (SPQ) (Raine, 1991) were also administrated to assess each participant's level in the spectrums of sensory processing and schizotypal personality, respectively. All assessments were conducted by the lead researcher or a graduate student. A 64 electrode EEG cap was used to record responses from the JOVI task.

## Participants

Data from 9 male and 8 female undergraduate university healthy participants, aged from 16 years to 21 years old ( $M = 18.4$ ,  $SD = 1.18$ ) was analyzed in this study. Partial data was collected from a total of 28 participants; however data from 11 participants were excluded due to noisy EEG data, voluntary withdrawals from the study, or not meeting the healthy participant criteria (e.g. some participants were excluded from the study prior to data collection due to meeting exclusion criteria such as active substance abuse, a current psychological disorder, a history of a psychological disorder, or vision abnormalities). Vision for included participants was near-normal or corrected-to-normal. Visual acuity was tested using a Snellen chart. Of the healthy participants whose data was included, three were left-handed, fourteen were right-handed. All students, regardless of data collection, received six research credits for participating voluntarily. All research participants provided written informed consent. Participants were asked that prior to the study they have a good night's sleep, wash their hair with shampoo, but no conditioner, arrive with no hair products on their hair, bring glasses or wear contact lenses if needed for corrected vision, and sign up for participation with a clear mental history.

## Procedure

All data collection sessions were collected between 9 am and 1 pm. All healthy participants were fitted with an EEG cap. Scalp EEG was obtained before, during, and after the JOVI task through a 64-channel active electrode system (BrainAmp MR Plus amplifier, Brain Product GmbH, Gilching, Germany). Direct current EEG data was low-passed at 1 KHz, digitized at 1 KHz, and recorded by Brain Vision Recorder software (Brain Product GmbH, Gilching, Germany). Abralyt HiCl abrasive electrolyte gel (EASYCAP GmbH, Herrsching, Germany) was applied to each electrode to obtain the necessary scalp-electrode contact. The



participants were then seated 100 cm away from a 24-inch computer monitor while wearing the electrode cap.

Prior to the start of the JOVI task, participants were shown an instructional screen, familiarizing them with the task they were being asked to complete. During this instructional time, participants were instructed to focus their attention on the center of the monitor screen, and were shown a sample of the one egg-shaped stimulus on the screen (see figure 1). We used a two alternative forced-choice method for this experiment. The jitter and spacing between contours were constant as well as the size, egg shape, and colors of the stimuli. The participants were asked to respond as quickly as possible via a Cedrus RB-834 response pad (Cedrus Corporation, San Pedro, CA), indicating the right or left of the pointing of an egg shaped contour. The subject was then asked if they were ready to begin their first block trial, and pressed the blue button when they were ready to begin.

Following the instructional screen, participants began their first block of items. A total of 320 contour stimuli were organized into four blocks of 80 contours each. The contours were given a low (0 degree, 7 degree, and 9 degree) or high (11 degree, 13 degree, or 15 degree) degree of orientation jitter (Fig. 2). Within each block of 80 contours, there were 5 sub-blocks: 0 degree sub-block, 7 degree sub-block, 9 degree sub-block, 11 degree sub-block, and 13 degree sub-block. Each sub-block contained 6 left facing sub-block degree specific (i.e. first block, 0 degree, second block 7 degree, etc.) jitter stimuli, 6 right facing sub-block degree specific jitter stimuli, 1 left facing 15 degree jitter contour, 1 right facing 15 degree jitter contour, and two randomized catch contours. Catch contours are used to evaluate if a participant is paying attention and would only be failed if a participant were responding randomly. The order of the contours in each sub-block were randomly generated for every participant via computer program

(Presentation; Neurobehavioral Systems Inc., Berkely, CA). Each contour was shown for 2 seconds. There was a 1 second inter-stimulus interval. After each block, the participant could relax and move their neck to prevent muscle stiffness. The participant was then asked if they were prepared to continue the next block, and pressed the blue button when they were ready to continue. This resting period occurred after every block until the fourth block was completed.

### **Data processing**

We analyzed the data for this study using BrainVision Analyzer 2.1.0 (Brain Product GmbH, Gilching, Germany). All EEG data were re-referenced to a new common average reference in all 63 other channels for all data. Afterwards, an IIR filter was applied to all data. The low cutoff frequency entailed .4 Hz at a 24 db/Oct slope at .3978873 second time constant. The high cutoff frequency entailed a 15 Hz at 24 db/Oct slope. The notch was set to 60 Hz to eliminate interference from the electricity network/line noise.

Data was recorded for each participant in four block chunks. Within each block, the segmentation function was applied, and data was separated by degree of jitter stimuli (0 degrees, 7 degrees, 9 degrees, 11 degrees, 13 degrees, and 15 degrees). The duration of segments chosen were all based on the stimulus-onset time from -500 ms to 3000 ms totaling a duration of 3500 ms. Within each separated stimulus segmentation, artifact rejection was implemented manually to remove segments with incorrect and timed-out responses to the stimuli and visible artifacts within a segment. Following this, baseline correction was applied from a range of -100 ms to -5 ms. The average transform was used to average the segmented data.

To separate the segmented data into low (0 degree, 7 degree, and 9 degree) or high (11 degree, 13 degree, or 15 degree) degree of orientational jitter groups, a grand average transform was performed within the two difficulties. For every high and low degree data group for each

participant, a peak detection of P200 on the Oz channel (i.e. midline occipital electrode) from 150 ms to 275 ms was performed to gain the latency and amplitude of the P200 component. This data was then exported for analysis in SPSS.

## Results

A general linear model analysis was run in SPSS for the data and the following post-hoc test using the Bonferoni correction. The descriptive statistics from the general linear model analysis are provided in Table 1. Data were analyzed using a within-subjects factor of latency, amplitude, difficulty levels, and blocks. Mauchly's Test of Sphericity indicated that the assumption of sphericity had been violated within-subjects block and amplitude ( $X^2(5) = 12.744$ ,  $p = .026$ ). Degrees of freedom were corrected using Greenhouse-Geisser corrections when the assumption of sphericity were violated.

A repeated-measures MANOVA was conducted to compare the effect of easy and hard difficulty of contour on P200 ERP latency and amplitude. For the multivariate tests, there was a significant main effect of difficulty, Wilks' Lambda = 0.461,  $F(2,11) = 8.777$ ,  $p = .003$ . No main effect was found across blocks, Wilks' Lambda = 0.431,  $F(6,11) = 2.423$ ,  $p = .569$ . No interaction effect was found between blocks and difficulty, Wilks' Lambda = 0.637,  $F(6,11) = 1.047$ ,  $p = .447$ .

For univariate tests, a significant main effect between easy and hard difficulty of contours on amplitude was found,  $F(1,16) = 18.284$ ,  $p = .001$ . An error bar graph ( $\pm$  standard error of means) was produced to show the main effect between mean amplitude of P200 and the difficulty level of jitter orientation (Fig. 2). A trend-level main effect between easy and hard difficulty of contours on latency was found,  $F(1,16) = 3.229$ ,  $p = .091$ . An error bar graph was produced to show the trend of mean latency of P200 and the difficulty level of jitter orientation

(Fig. 3). Confidence interval and standard error data are provided in Table 2. There was no interaction found between block number and latency,  $F(2.18, 34.89) = 1.641, p = .207$ , (Greenhouse-Geisser corrected p-value). No interaction was found between block number and amplitude,  $F(3, 48) = .741, p = .533$ .

## Discussion

The contour element linking process is thought to be executed in the ventral tempero-occipital stream where orientation and size in V1, contour and form in V2, and shape in V4 are processed due to its main role in object recognition (Ungerleider & Pasternak, 2004; Butler et al., 2008; Silverstein et al., 2011). The magnocellular pathway to the dorsal parieto-occipital stream, is believed to initially detect coarse spatial structures in order to segregate objects such as the Gabor contour from background stimuli (Kaplan, 1991; Merigan & Maunsell, 1993; Butler et al., 2001, 2008). In contrast, the parvocellular pathway, which is the primary source of the ventral tempero-occipital stream, is believed to code the fine spatial details of objects (e.g. co-linear orientations across neighboring Gabor patches) (Kaplan, 1991; Merigan & Maunsell, 1993; Butler et al., 2001, 2008). Wynn and colleagues (2015) suggest that visual integration deficits may occur at early stages of ventral stream processing in V1 and V2.

The present study was conducted using JOVI, a contour integration task, to investigate visual integration by analyzing P200 component latency and amplitude in healthy subjects. This contour integration task was used in previous studies (Silverstein et al., 2000; Silverstein et al., 2009; Butler et al., 2013) but the P200 component was not focused on in these studies. In this study, solely the visual waveform P200, whose peak latency ranges from 150 to 275 ms (Brenzitz, 2008), was analyzed. The auditory-lingual P200 component has been investigated rigorously (Roth, Pfefferbaum, Berger, & Kopell, 1981; Shenton et al., 1989; Rentzsch, de

Castro, Neuhaus, Jockers-Scherübl, & Gallinat, 2007; Lijffijt et al., 2012) however the visual P200 component has been far less researched. The limited amount of research conducted on the visual P200 component, and the lack of knowledge about the nature of the component (Breznitz, 2008), created a focus point for this study. We strove to study the visual P200 ERP response to low versus high degree jitter contours in order to gain further knowledge on the integration of stimuli.

Supporting our first hypothesis, a main effect between P200 amplitude and difficulty level was found. The mean P200 amplitude was larger when the orientation jitter was higher and contour detection was more difficult (see Fig. 4). An electrophysiological graph showing the mean difficulty jitter orientations and P200 amplitudes for subjects illustrates these findings (see Figs. 5 & 6). Our results are similar to the N120 and Nc1 component amplitude and difficulty main effect result reported by Butler and colleagues (2013). Also, a trend between latency and difficulty was shown, and we suggest that it is likely that our findings are an artifact of the difficulty variance. Breznitz and Meyler (2003) suggest that the latency of P200 reflects the speed that stimuli are evaluated, implying that latency is dependent on task difficulty. A time constraint limited the participant pool data that could be collected, but also due to the long list of exclusion criteria for this study, many participants screened out of our study, resulting in our data analysis being limited to seventeen participants. More data from participants could have yielded a stronger correlation between latency and difficulty.

We expected to find an electrophysiological effect from practice between the 1<sup>st</sup> block and the 4<sup>th</sup> block on latency or amplitude, but our data does not support this. Pernet et al. (2003) suggested that P200 is involved with implicit memory of stimuli, due to their findings of over-learned stimuli resulting in short P200 latency and unfamiliar stimuli resulting in longer P200

latency. These findings suggested that there could be a potential electrophysiological effect from practice between blocks. Perhaps a larger sample size could yield a significant electrophysiological data effect from practice. Also, maybe the findings that support an electrophysiological effect from practice between blocks could be supported with data, but at a later cognitive latency component such as N400 or P600 or at an earlier component such as N100. Further research should be conducted to investigate this hypothesis.

We found that the number of correct responses from participants for the 15 degree contour, our highest contour, was at random guessing probability ( $M = .510$ ,  $SD = .625$ ) compared to our 13 degree contour, where the number of correct responses across subjects was higher than random guessing probability ( $M = .625$ ,  $SD = .141$ ). This data suggests that visual integration of the 15 degree contour shape possibly did not occur, and only the contour elements were visually perceived and the contour direction response was a guess. This type of element perception could possibly have been producing a similar electrophysiological response, but from a different stimulus process than expected. As the contour jitter orientation gets higher, the ability to perceive the shape of the egg is reduced (Silverstein et al., 2009). Perhaps at a certain jitter orientation, people can no longer perceive the contour at all. Visual integration is the process that fuses local visual environmental information to form a cohesive complex higher-order visual image (Kozma-Wiebe et al., 2006; Silverstein et al., 2011), and analyzing a response that reflects a failed inability to form a cohesive visual image would result in confounded data. We suggest that studies that used contours with jitter orientations much greater than 15 degrees (Silverstein et al., 2009, 2011; Butler et al., 2013) could be flawed in design possibly due to inaccurate electrophysiological responses at these higher jitter orientations. Future studies should be wary of using Gabor contours with jitter orientations larger than 15 degrees.

Another limitation of the study includes the lack of generalizability due to the college student population being the participant sample. According to recent findings, the brain does not reach full maturity until approximately the mid-20s, including the occipital lobe (Giedd, 2004). However, our data was collected from participants 16 to 21 years old, producing a large developmental gap in terms of brain development. Silverstein and Keane (2011) report that perceptual organization mechanisms do not become fully mature until late adolescence or early adulthood. For our participants, the magnocellular and parvocellular pathways, V1, V2, V3, and V4, as well as the ventral temporo-occipital and dorsal parieto-occipital streams that are involved in visual processing (Butler et al., 2008) may not be fully developed. Varying developmental stages of perceptual organization mechanisms could yield inconsistent data. Perhaps future research should focus on a cohort ages 25 and older to avoid this possible variance. Similarly, our study initially was going to exclude left-handed participants using the Edinburgh Handedness Questionnaire (Oldfield, 1971), however due to an already small amount of eligible participants, left-handed participants' data was not excluded. However, the inclusion of left handed participants could have confounded our data due to visual processing hemispheric dichotomy between dominant left versus right handed individuals (McKeever & VanDeventer, 1977).

The number of participants in this sample produced data that is inadequate to generalize to the population. The time constraint on this study limited the number as participants as well as the types of participants we wanted to include in this study. The primary researcher and graduate students are currently still collecting data from healthy participants as well as from patients with schizophrenia at a local hospital psychiatric facility. The ultimate goal is to further collect healthy participant EEG visual integration data as well as EEG visual integration data from patients with schizophrenia, and analyze multiple ERP components, including P200, to satisfy

the CNTRICS (2011) initiative of identifying the impaired cognitive systems and component processes to then be able to target them for treatment development for schizophrenia.



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Table 1

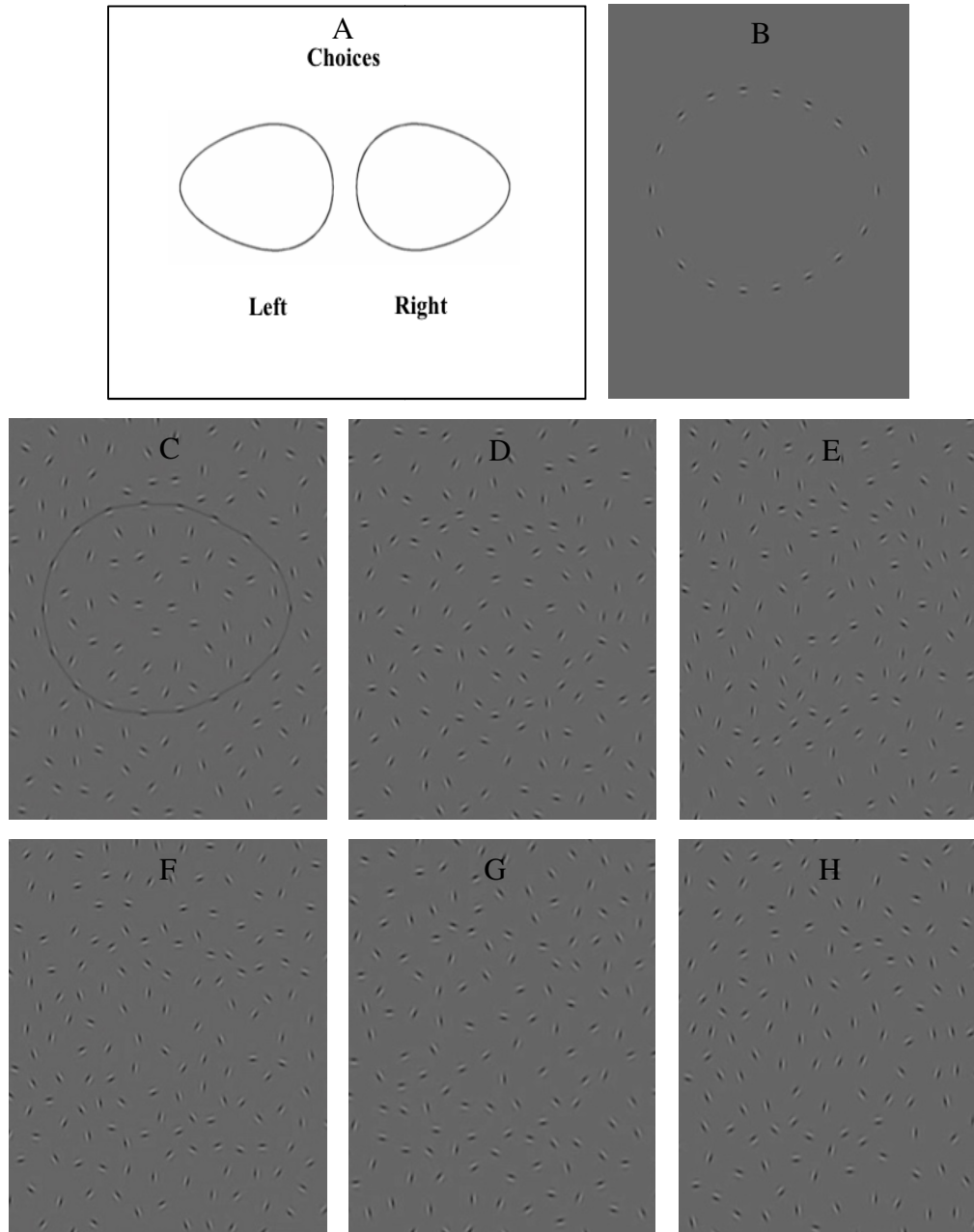
Descriptive Statistics					
Measurement	Block	Difficulty	Mean	Std. Deviation	N
Latency	1	Easy	220.47	28.023	17
	1	Hard	223.94	25.827	17
	2	Easy	224.24	26.962	17
	2	Hard	223.94	27.031	17
	3	Easy	226.29	27.719	17
	3	Hard	228.06	27.976	17
	4	Easy	219.35	24.459	17
	4	Hard	225.88	26.27	17
Amplitude	1	Easy	5.105847	5.209389	17
	1	Hard	6.937781	6.520563	17
	2	Easy	3.709384	3.719118	17
	2	Hard	6.090547	3.976626	17
	3	Easy	4.199614	4.778743	17
	3	Hard	6.418005	4.386775	17
	4	Easy	4.989121	4.418925	17
	4	Hard	5.766971	5.065326	17

*Note.* Latency was measured in ms and Amplitude was measured in  $\mu\text{V}$ .

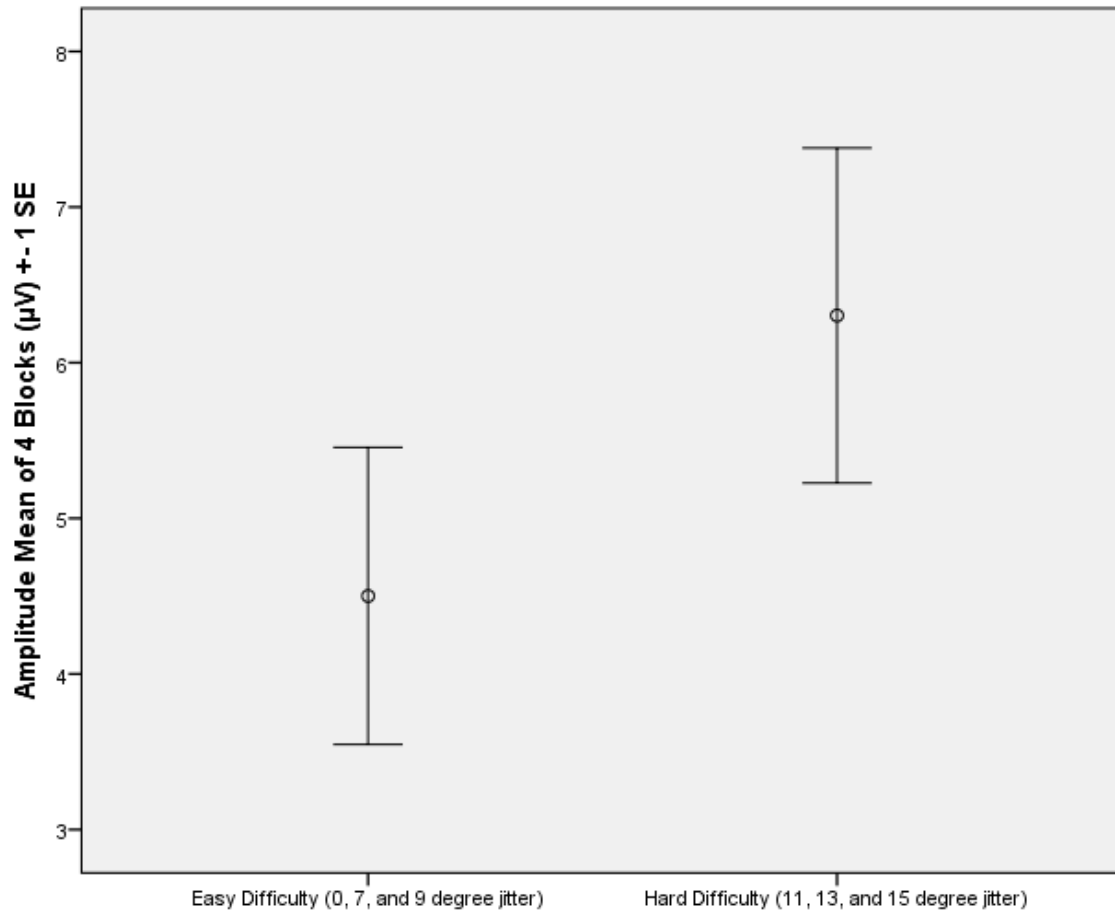
Table 2

Pairwise Comparisons								
Measure	Difficulty	Mean	Standard Error of the Mean	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound	Mean Measure Difference	Mean Measure Difference Standard Error	Sig.
Latency	1	222.588	6.292	209.25	235.927	-2.868	1.596	0.091
	2	225.456	6.098	212.529	238.383	2.868	1.596	0.091
Amplitude	1	4.501	.954	2.478	6.524	-1.802	0.422	0.001
	2	6.303	1.076	1.076	8.585	1.802	0.422	0.001

*Note.* Latency was measured in ms and Amplitude was measured in  $\mu V$ .

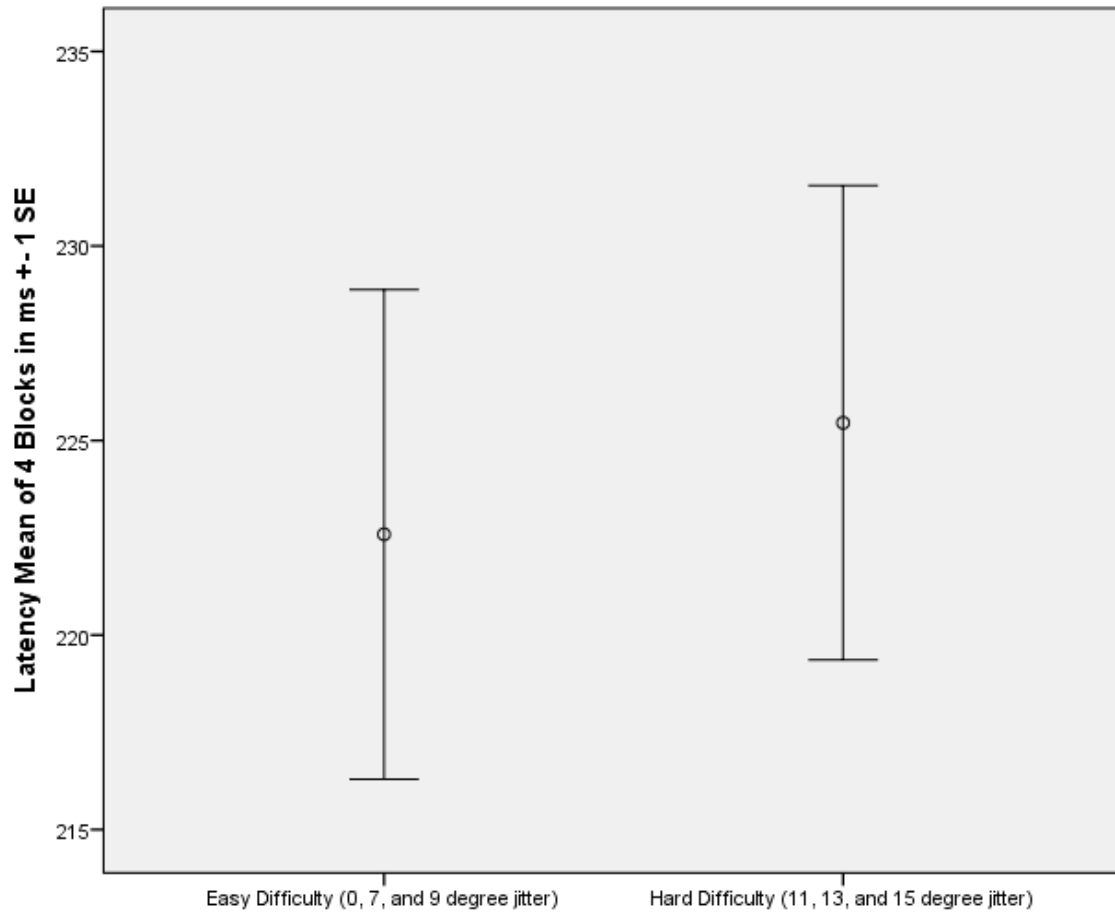


*Figure 1.* Right-facing Gabor contours for the Jitter Orientation Visual Integration Task. A: The forced-choice options. B: Catch trial. C: Contour pop-out 0-degree jitter orientation. D: 7 degree jitter orientation. E: 9 degree jitter orientation. F: 11 degree jitter orientation. G: 13 degree jitter orientation. H: 15 degree jitter orientation. C-E: Easy difficulty jitter orientations. F-H: Hard difficulty jitter orientations.

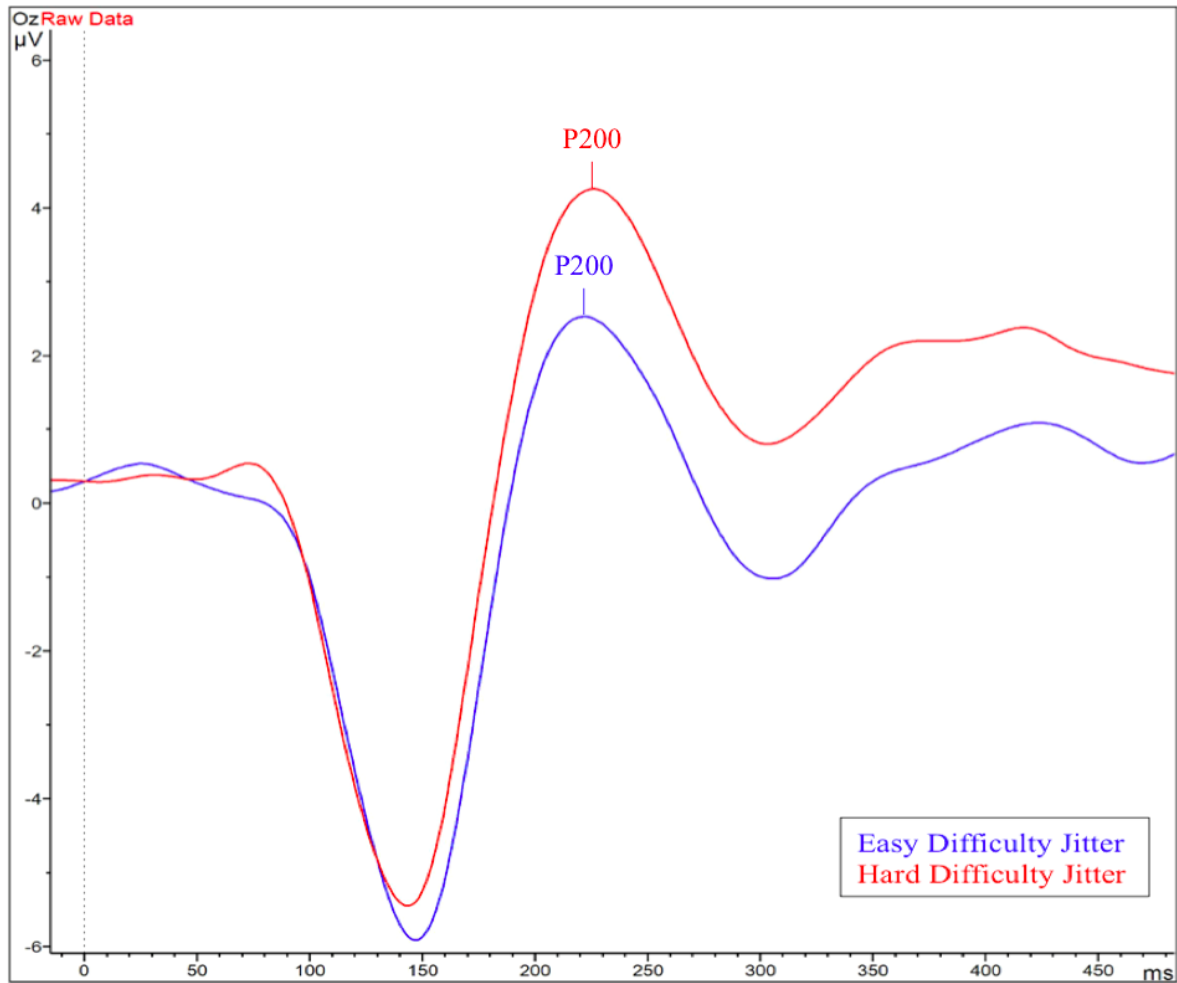


*Figure 2.* This error bar graph is used to show the main effect between mean amplitude of P200 across four blocks (in microvolts) and the difficulty level of the jitter orientation.

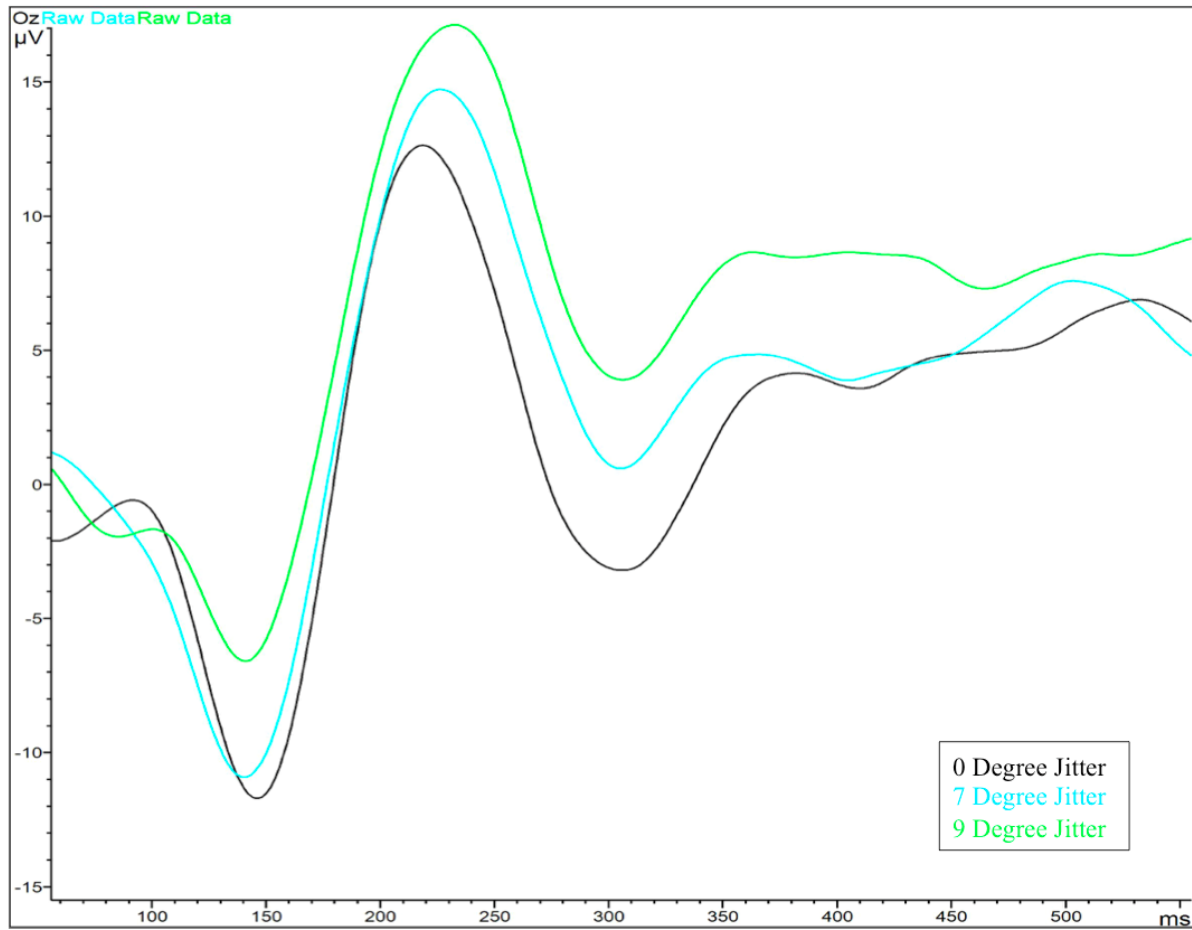




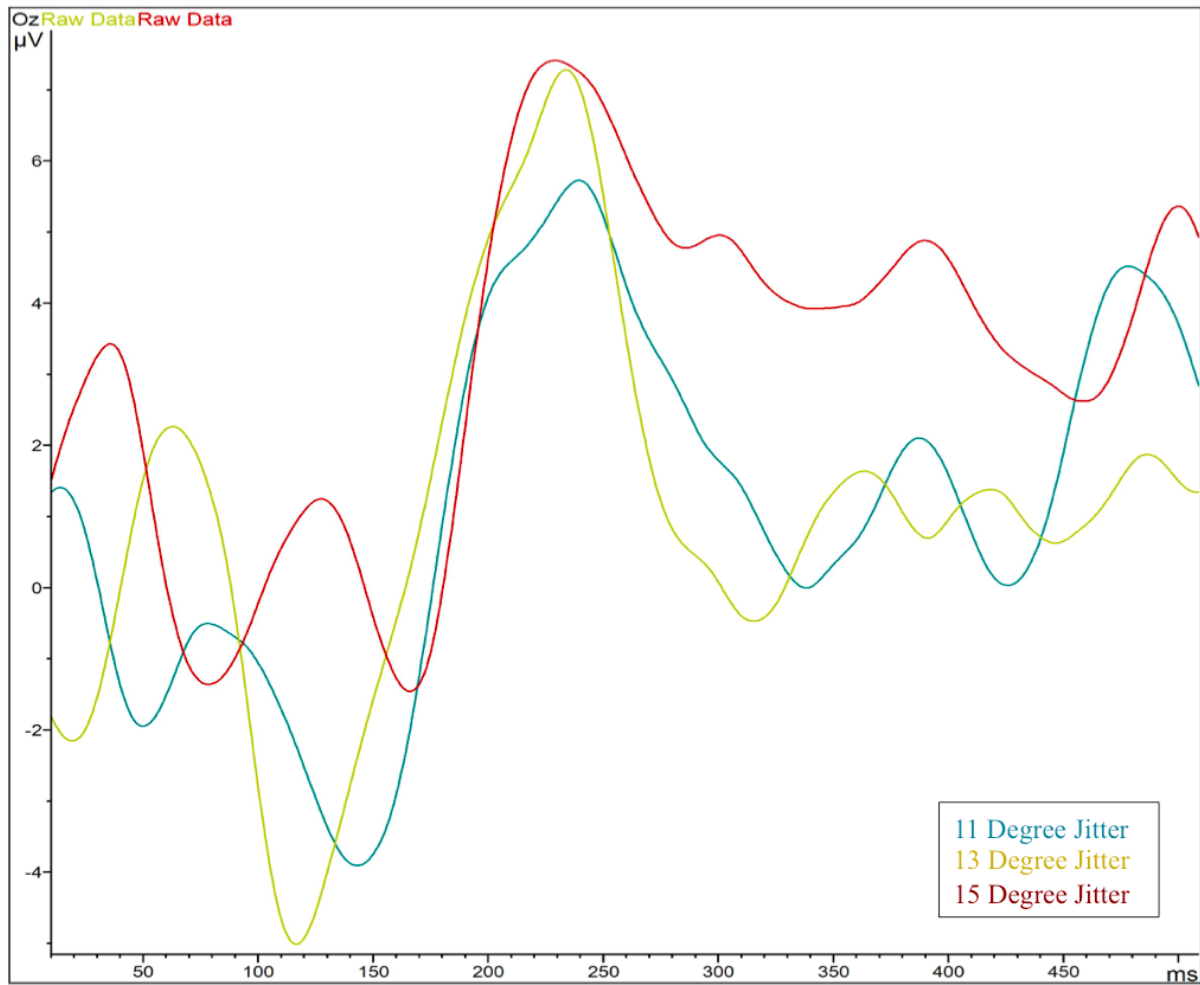
*Figure 3.* This error bar graph is used to show the trend between mean latency of P200 across four blocks (in milliseconds) and the difficulty level of the jitter orientation.



*Figure 4.* This electrophysiological response graph is used to show the differences between hard difficulty and easy difficulty jitters through grand average latency and amplitude of P200 for all subjects across all blocks.



*Figure 5.* This electrophysiological response graph is used to show P200 amplitude and latency differences from one subject for the three easy difficulty jitter orientations.



*Figure 6.* This electrophysiological response graph is used to show P200 amplitude and latency differences from one subject for the three hard difficulty jitter orientations.